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NOTES AND LITERATURE

VALUATION OF THE SEA¹

It is very interesting to see a small country like Denmark lead so prominently in several lines of ecologic study. The nestor of plant ecologists, Warming, has done his work here. The ecology of fresh-water animals, particularly the plankton, has been studied by Wesenberg-Lund; the marine animals have been persistently studied by Dr. C. G. Joh. Petersen, and the ecological interrelations of the vegetation and the animals (particularly the fish) have been studied recently by the plant ecologist Ostenfeld. And although this is not all that has been done, it shows very clearly the network of problems on sea and land which has been studied from a modern ecological standpoint.

The paper now under consideration is one of the latest ecological contributions to a study of the conditions of life upon the sea bottom. The senior author, Dr. Petersen, has been at work on these problems since 1883. This long interval affords him a splendid opportunity to observe the character of the changes on the sea bottom. He says: "The impression of the fauna as a whole remains, however, unchanged within such a short period of time as one generation. This holds good for the Kattegat and the Baltic, thus for comparatively open and large stretches of water." Through his studies of the fishes, particularly the plaice, he came to the conclusion that, "To understand the distribution of animals right on the bottom, we must study the occurrence of each species throughout the whole of its life." When he learned that the plaice from the western part of Limfjord were inhibited in growth for 8 months, but when transported to its central part they increased four to five times their original weight, he concluded that serious attention must be given to their food. The cause for this difference he thought was due to the relative amounts of food present—but how was this to be determined? This led to a long series of experiments in methods of

¹"Valuation of the Sea. I. Animal Life of the Sea-Bottom, Its Food and Quantity" (quantitative studies). By C. G. Joh. Peterson and P. Boysen Jensen. Report of the Danish Biological Station to the Board of Agriculture, Vol. XX, pp. 1-76, Plates VI, 1911. Translated from "Fiskeri-Beretning for 1910." Copenhagen.

taking bottom samples by means of an apparatus attached to a long pole. By means of such methods he and his former assistant compared the number of animals per square meter. Dahl (1893) had made quantitative studies of the sea bottom at low tide by digging and the quantitative investigations by Petersen are believed by him to be the first made off shore. To improve these bottom studies a new apparatus was devised for work in deeper waters and the results of the present study are the first product of this new device, which permits samples of the bottom to be brought up in their natural position. Detritus collectors were also used in these studies. With the new sampler it was found that when food was abundant on the bottom there was a surface layer of *brown* or gray, and when the food was scanty this layer was black and malodorous. In view of the fact that the digestive tube of most of the animals which were not vegetable feeders or predaceous, contained a substance much like the surface *brown* layer, Petersen decided to investigate this subject more fully. The bottom layer he calls the "dust-fine detritus." This layer in addition to its inorganic parts consists of plant and animal remains, including some plankton organisms. Here then is a very much neglected source of food, and he remarks: "We have so long and so often heard of the rôle the plankton is considered to play in the economy of the sea, that we almost forget the other sources of food, which, however, at any rate in the smaller waters, certainly have even greater importance."

The dependence of animals upon plants for nutrition is just as intimate in the sea as upon the land. Therefore to understand the transformation of substance in the sea from the inorganic to the various kinds of animals one must begin with the marine plants. This phase of the subject was investigated by Jensen. In addition to the plankton plants there are those attached to the bottom, the algæ and grass wrack *Zostera*. The plankton of the North Sea is more abundant than in the more enclosed waters of the Kattegat. This plankton is not an important source of organic material; the main supply on the bottom is therefore either the algæ or the *Zostera*. Jensen shows that a characteristic feature of the metabolism of the sea is that the organic materials do not remain where they are formed but tend to become widely distributed, more or less uniformly over large areas. This might well be called Jensen's law. The vegetation

of the sea, on account of its very limited range, except the vegetable plankton (and bacteria), is in marked contrast with that on land. And if it were not for the broadcast scattering of plant remains "the greater part of the bottom of the sea would be bare, not only of vegetation, but also of the animal life dependent on the vegetation." The source or sources of bottom deposits was now investigated in detail. In this connection the origin of the bottom deposits in Danish lakes is instructive. Wesenberg-Lund has found a considerable amount of organic materials on the bottom of these lakes. This layer is eaten by animals and a bottom soil is formed which has passed through the digestive systems of animals. This material is called *gytje* and is "formed in pure clean water chiefly by the excremental agency of the bottom-fauna." These organic materials are derived from the land, the littoral zone, or from the plankton. In deep lakes the plankton materials are dissolved before they reach the bottom, but in shallow lakes the soft parts of the plankton are also added to this layer. This condition naturally calls to the reviewer's mind the activity of earthworms in the soil, and Dall's² discussion of the banks of excrement formed by fish on the borders of the continental slopes.

Returning now to the bottom deposits in Danish waters, it is interesting to note the character of the organic bottom layer. This forms a brown layer from 1-2 mm. thick, composed of fluffy fine materials, both organic and inorganic. When tested for cellulose but little was found, but large amounts of pectose were present and similar relations resulted in tests of *Zostera*, thus supporting the view that *Zostera* was an important source of this organic material. Below this upper layer is a dark blue one, and both layers are free from odor. This kind of bottom is found in depths of more than 6 meters. When these bottom samples are examined it is found that the amount of carbon is greater when *Zostera* is abundant, rather than when plankton is abundant, and therefore Jensen concludes that the "main source of organic matter in the sea bottom must be due to the *Zostera* belt and not to the plankton organisms." Bottom samples taken out at sea show that there is a progressive diminution of carbon with distance from the shore, and therefore he again concludes that: "the organic matter in the sea bottom is mainly derived from the benthos formation at

² *Pro. Biol. Soc. Wash.*, Vol. 5, pp. 10-11, 1890.

the coasts. . . . The result of these investigations is, therefore that the plants of the *Zostera* belt and not the plankton organisms constitute the principal source of the organic matter in the sea bottom." And this is in harmony with Petersen's contention that *Zostera* "is certainly the plant, which for a great part conditions the fish-wealth of our coasts and attracts the fishes from the open and deeper waters into the shallow, enclosed bays and fjords." These are very important conclusions and deserve the careful consideration of students of marine animals in other localities. These investigations may well serve as models for investigators in many other regions, and this point of view should also be applied to lakes and streams.

When the black, foul-smelling bottom layer is examined it is found to contain much methane or marsh gas, probably due to the activity of bacteria, small amounts of oxygen and carbon dioxide. The black color is mainly due to ferrous sulphide, which in fresh water is mainly due to the reduction of sulphates by anerobic bacteria. These black muds contain the greatest amounts of organic materials. These soils are most abundant in the inner fjords, and they represent an early stage of the conditions, which in its extreme development is found in the Black Sea. Jensen states that he does not know of a similar condition of affairs in fresh water where he is inclined to think such a condition is prevented by humic acid. This recalls the phenomenon of "stagnation" which Whipple and others have studied in American lakes, and which is even occasionally found in rivers heavily charged with sewage. He concludes this chapter with this striking sentence: "We may therefore, to a certain extent, regard the large oceans as the lungs of the sea, which supply the water-masses of the inner seas with oxygen and remove the superfluous organic matter."

Jensen next considers the transportation of the organic materials from its course near the shores to the bottom. The winds are found to be an important agent in the process, as is shown by the presence of a larger amount of débris in the water after storms. By centrifuging this material is removed from the water, and when examined microscopically it is found to be composed mostly of materials so finely divided that it is not possible to recognize its source. Examined chemically, as well as microscopically, it is found to be "completely identical with the uppermost brown layer on the sea bottom."

The food of the animals of the Danish fjords is discussed by Petersen. The oyster has commonly been considered as a plankton feeder, although the materials found in its digestive tube are indistinguishable from the surface brown layer of the bottom and Petersen believes that the oyster feeds, in the main, upon the organic parts of the dust-fine detritus. The growth of oysters on objects raised from the bottom has been supposed to support the view that they were plankton feeders, but now since it is known, through the use of the centrifuge, that "pure" water contains the dust-fine detritus which is everywhere available, it also supports the view that the oyster feeds upon this as well. Petersen remarks that Lohmann was the first to recognize this detritus as an essential source of food for plankton animals, and now Petersen gives it much greater extension and importance. Thus in the past a clear distinction has not been made between the ordinary plankton and detritus feeding animals. Such feeders may be divided into two classes, those which filter the material out of the water, and those which take it off the bottom. In addition to the oyster the food of several other animals is considered, such as Echinoderms, shrimp and *Cardium*. He observed in an aquarium that the long-siphoned bivalve *Abra* sucks in through the siphon the surface layer of detritus and he suggests that the short-siphoned bivalves probably take their detritus directly from the water. To the reviewer it seems that here are several important suggestions for the students of our American Unionidæ. These molluscs are probably detritus feeders also, rather than wholly plankton feeders, and this may be a factor in their greater development in streams, compared with ponds and lakes, on account of the superior powers of streams in transporting detritus and other food.

Instead of taking up the food relations of each species, Petersen decided upon a larger unit, the animal community of Limfjord, Thisted Bredning, and he studied the mass of animals living on a square meter of the soft bottom. A review of the food relations of such a sample area showed that it was "*a detritus-eating Lamellibranch-worm community with its predatory animals*. This animal community forms the basis for a great part of the fish-life there." There are other communities. Thus nearer the shore in about 5 meters and less of water the *Zostera* zone begins, and this is a region which has not been

investigated quantitatively. Here the dominant animals are small gastropods, *Rissoa*, *Littorina*, Nudibranchs, *Mytilis*, Amphipods, Isopods and numerous animals which abound in *Zostera*. Shoreward from this zone is the sand bottom, and finally the strand, each with its characteristic animals and food habits. Such a study calls to mind Möbius's description of the oyster bank as a biocenose. In discussing the food relations of these communities Petersen adds a word of caution to those who in the future use the word plankton. They should not use it without stating exactly what is meant, whether plankton captured by a net, that which is small enough to pass through the net, and the detritus plankton. In summing up the general relation of these communities Petersen remarks: "All seems to me to indicate, that the greatest mass of the bottom-fauna per square unit is to be found in the smaller waters, where the bottom-flora occurs at least in the neighborhood, whilst the bottom of the oceans is as a rule to be regarded as waste regions. . . . One thing is certain, at any rate, the great, rich fisheries are not prosecuted on the open oceans, but always in more or less close proximity to the coasts or in the smaller waters."

For a detailed study of the productivity of the different kinds of bottom Petersen found it necessary to devise various forms of bottom samplers, so that the mass of life for a unit area of bottom might be determined. His investigations in this line were begun in 1896, but his earlier results were not published. His latest invention is a bottom sampler which permits one to secure a specimen of soft bottom, with the layers of mud in their natural position, from an area of about one tenth of a square meter. The animals are taken from this sample and their rough weight and dry weight are determined. The dry weight is believed to be the most precise estimate of the amount of life which a given unit area of bottom can produce. The many difficulties encountered in making such determinations are discussed fully, because he was eager to make, if possible, some calculation of the annual production of such a bottom. The fish are estimated to consume about 3 grams per square meter, and the whelks and starfish may eat twice as much food substance as the fish, or about 6 grams dry weight per square meter. For the Thisted Bredning, he estimates that the total amount of dry matter on the bottom is about 30 grams per square meter. He estimates

that the bottom fauna reproduces its own mass each year, and consumes its own weight of food several times during the same period. Of course these estimates are provisional.

A very interesting and unique feature of this report is the series of four large diagrams which show the relative density of the population of the sea bottom. Each diagram represents one fourth of a square meter and its population. The drawings are natural size and show the average fauna. The suggestion is made that such quantitative pictures of the sea bottom would be suitable for museum exhibits, and progressive curators will no doubt utilize this idea.

This is a paper of more than usual interest, and one which will appeal to a variety of students. The general physiologist will be particularly interested in it for its bearing on the problem of the metabolism of the sea, the ecologist for the mutual food relations of the plants and animals, the economist and fish culturist for its bearing on the problem of increasing the economic productivity of the sea, and the paleontologist, the geographer and the oceanographer each in turn will find much of interest.

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